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The Association between Pediatric Overweight and Ankle Injuries: A Case-Control Analysis

Ellen Margaret House
Yale University

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**THE ASSOCIATION BETWEEN PEDIATRIC OVERWEIGHT AND
ANKLE INJURIES: A CASE-CONTROL ANALYSIS**

A Thesis Submitted to the
Yale University School of Medicine
in Partial Fulfillment of the Requirements for the
Degree of Doctor of Medicine

by

Ellen Margaret House

2008

THE ASSOCIATION BETWEEN OVERWEIGHT AND ANKLE INJURIES: A PEDIATRIC CASE-CONTROL ANALYSIS. Ellen M. House, Mark R. Zonfrillo, Jeffery A. Seiden, Robert Dubrow, M. Douglas Baker, David M. Spiro, Eugene D. Shapiro. Department of Pediatrics, Yale University, School of Medicine, New Haven, CT.

Pediatric obesity has become a worldwide pandemic and trauma is the leading cause of pediatric morbidity and mortality. Our hypothesis is that being overweight increases the likelihood of acute ankle injuries in children.

Our study consisted of a case-control analysis in an urban pediatric emergency department with subjects between 5-19 years of age. Cases consisted of children presenting with acute ankle injury; controls had chief complaints of fever, headache, or sore throat. Demographic information, physical activity score, heights, and weights were obtained on all participants; injury severity was calculated for the cases. Age and gender specific body mass index percentiles were calculated for all participants and a multivariate logistic regression was employed to assess the association between overweight and ankle injury. We also examined those ankle injuries that were not enrolled to assess for possible enrollment bias through comparison of weight percentiles and a sensitivity analysis of increasingly more unlikely assumptions.

One hundred and eighty cases and 180 controls were enrolled. A significant association was observed between overweight and ankle injuries (multivariate-adjusted odds ratio 3.26, 95% confidence interval 1.86-5.72, *P* value for trend < 0.0001). Due to possible enrollment bias, this result might overestimate the magnitude of the association, however our sensitivity analysis demonstrated the robustness of the statistical significance of our findings. In summary, overweight children may be at increased risk for acute ankle injuries.

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I. INTRODUCTION

PEDIATRIC OBESITY

Increasingly acknowledged by popular media, childhood obesity has become a worldwide epidemic affecting both developed and developing countries, irrespective of age, gender, ethnicity, or socio-economic status. Globally, one in ten children is overweight (1) creating more than 155 million overweight children worldwide. (2) Simply looking at children under the age of 5, there are more than 22 million children who are severely overweight. (1)

The prevalence of childhood obesity has increased in almost every country that has available data on pediatric weight trends. The limited exceptions were found in school age children in Russia and Poland during the 1990s as well as among infants and pre-school children in lower-income countries, such as in Africa. The most significant increases in obesity and overweight have been found in developed countries and urban centers. (3) It is estimated that the proportion of school-aged children worldwide who are overweight will double from estimates gathered from 1990-2003 as quickly as 2010. (1)

The global prevalence of overweight children incorporates a wide range, from Africa and Asia where the prevalence of overweight is well below 10%, to the United States and Europe where the prevalence is above 20%. In the European Union, the prevalence of overweight children is expected to rise by 1.3 million children each year, with more than 300,000 becoming obese, if there is no definitive and effective intervention. It is estimated that by 2010 approximately

26 million children in the European Union will be overweight, with 6.4 million classified as obese. (1)

Body mass index (BMI), a measure of weight compared to height (kg/m^2), is commonly used to classify 'overweight' (BMI 25.0 to 29.9) and 'obesity' (BMI ≥ 30.0) in adults. For the pediatric population the same calculation is used to classify children who are 'overweight' (BMI percentile ≥ 95) or 'at risk for overweight' (BMI percentile ≥ 85 to < 95) as compared to their age and gender matched peers. Some studies have instead used the terms 'overweight' and 'obese' for children, however sensitivity to the power of labeling has led to a switch in terminology to the more appropriate 'at risk for overweight' and 'overweight' categories for children. As of 2004, 34% of children in the United States were classified as either overweight or at risk for being overweight (4) easily making the issue of overweight both common and problematic in the American pediatric practice.

In the United States (US) obesity prevalence is monitored by The National Health and Nutrition Examination Survey (NHANES). The survey uses stratified, multistage, probability samples of the civilian, non-institutionalized, US population through household surveys and physical examinations of each participant. These examinations are conducted in mobile examination centers where heights, weights, and other body measurements are obtained. The original NHANES surveys showed relatively stable obesity and overweight prevalences from its inception up until the 1980's. However, from the NHANES II (1976-1980) to the NHANES III (1988-1994) the prevalence of overweight in American

children almost doubled. From the NHANES II until the most recent set of reported data in 2003-2004, overweight prevalence in 2-5 year olds has increased from 5 percent to 13.9 percent; in 6-11 year olds it has gone from an estimated 7 percent to 18.8 percent, and in adolescents aged 12-19 years the prevalence of overweight has increased from 5 percent to 17.4 percent. (9) When following the trends of overweight prevalence in all age groups across all the NHANES surveys starting in 1963, it is obvious that overweight prevalence has not decreased, and instead continues to climb. In short, since the 1980's, in the US adult obesity has doubled, child (6-11 yrs) overweight has doubled, and adolescent (12-19 yrs) overweight prevalence has tripled. (5)

Although prevalence of overweight has increased across age, gender, ethnicity, and socio-economic lines, disparities do exist. Amongst American adults, non-Hispanic black women have the highest prevalence of overweight and Mexican-American men have the lowest. Currently, no disparities have been noted between men of different races or ethnicities, although amongst women non-Hispanic black and Mexican-American women have the highest prevalence of overweight and obesity. In American children, Mexican-American boys have the highest rate of overweight, and non-Hispanic white girls have been noted to have the lowest.(4)

The National Heart, Lung, and Blood Institute's Growth and Health Study in 1985 attempted to address the obesity disparity that exists between white and blacks and determine whether it was due to psychosocial, environmental, or socioeconomic factors. The study was carried out in four centers and enrolled

1213 black and 1166 white girls between the ages of 9 and 10 years old and then followed them until 18 or 19 years of age. Skin-fold measurements, BMI, lipid levels, stage of sexual maturation, psychosocial factors, dietary habits and physical activity scores were obtained on all subjects. (6) In a number of papers published based on the study results (6, 11), it was shown that at 9 years of age, black girls' median BMI was 2.3 kg/m² higher than their white counterparts, and at 19 years of age the disparity had widened to 6.9 kg/m². Triceps skin-fold measurements were also greater in black girls than white at 12 years of age.

Geographically, the swiftest increase in prevalence of overweight has been seen in the South Atlantic region, where Maryland, Virginia, Georgia, and Florida demonstrated a greater than 70% increase in overweight prevalence in the 1990's alone. (7) Socio-economic status is clearly associated with adult obesity; however, with children the association is less clear. For children and adolescents, the family income is not reliably associated with rates of overweight in non-Hispanic blacks and Mexican Americans. However, non-Hispanic white adolescents from lower income families do experience a higher prevalence of overweight. Family education level can also be predictive of the likelihood of overweight; for non-Hispanic white children, the likelihood of being overweight is inversely related to the highest education level of the reference family member. (8)

In relation to age, the general trend is that increasing age in Americans leads to an increased likelihood of being overweight. Adolescents are more likely to be overweight or at risk for overweight compared to younger children, and

older adults are more likely to be obese than younger adults. The only cohort that does not keep to this trend is adults 80 years and older, who had the same prevalence of overweight as adults 20-38 years of age. (9)

The reason for the development of the pediatric obesity epidemic has been highly debated, as have the individual risks for developing obesity. The general consensus is that obesity and overweight are usually a result of imbalances between calories consumed and energy expended. Changing trends in these two domains are likely responsible for the increasing weight of the global population. Changing trends in calories consumed and energy expended, however, exist in the milieu of environment, genetics, and individual lifestyle.

The exact genetic predisposition underlying the development of overweight is still largely unknown, however the effects of genetics are undeniable. If neither parent is obese, then only approximately 9% of their children will be obese. If one parent is obese and the other is of normal weight, then half of their children will become obese. (21) If both parents are obese, it has been shown that two-thirds of their children will become obese. (10) Further, almost no discordance in weight exists between identical twins. (21) Therefore, it is clearly seen that environment alone cannot be used to explain the rates of obesity within families.

There have been a number of specific genes identified that contribute to the development of obesity, such as the *ob* gene and its product leptin, the agouti gene, and the *db* gene. (21) Obesity genes likely exist as they might have historically provided a survival advantage, allowing people to store energy as fat

in times of plenty and therefore survive longer during periods of famine. However, in the current milieu of caloric plenty and decreased energy expenditure, these genes are contributing to resultant morbidity of the current obesity epidemic.

Longitudinal studies have been the preferred method for analyzing the specific contributions of various dietary and activity factors in the development of overweight. Various studies have indicated that in the United States there has been an increase in calorie consumption without any accompanying increase in physical activity. (9) Physical activity disparities have been used to explain some of the differences between the prevalence of overweight in white and black children. Physical activity declines amongst both black and white girls as they age, but by the age of 17, 56% of black girls report no habitual physical activity outside of school, in comparison to only 31% of white girls who weren't active outside of school. (11)

For infants, the use of formula or mix-feeding has been associated with an increased risk of being overweight in childhood whereas breastfeeding is protective against the development of overweight in childhood. Looking at dietary habits of children, the only clear diet choice associated with the development of obesity is sugar-sweetened beverage consumption. At this time various studies have shown that becoming overweight or obese is not associated with snacking, fast food, or portion sizes (12).

Behaviors that have been linked to becoming overweight in childhood have included buying lunch at school, eating dinner while watching television or

without family member supervision, skipping breakfast, or consuming fewer calories at breakfast than at dinner. Overall the most robust risk factors associated with the development of childhood obesity include lack of breastfeeding, high early energy intake, and sugar-sweetened beverages. (12) Other factors include: the tendency to eat out more often; increased television, computer, and electronic gaming times; changing labor markets; and an increased fear of crime whereby parents discourage their children from outdoor exercise. (9) Weight promoting eating practices have been theorized to be the reason that black girls have a higher prevalence of overweight than their white counterparts. One study followed black and white girls over a period of five years and noted that black girls more often had weight-promoting eating practices than their white counterparts, such as eating when not hungry, sneaking food, eating while doing homework or watching television, and eating fast food. (13)

Examination of these risk factors has provided various targets for public health intervention in the childhood obesity epidemic. Beyond targeting lack of breast feeding and removal of sugar-sweetened beverages from schools, other targets for intervention include maternal risk factors. Long term risk factors that can be addressed which have been proven to increase the likelihood of a child becoming overweight are low birth weight, high birth weight, and a pregnant woman's nutrition. (14) In addressing the preschool population, targets for overweight intervention include reduction of maternal smoking during pregnancy, decreasing childhood television use, and moderate evidence suggests increasing physical activity. (15) Overall it is recognized that intervention must be within

the interconnected framework of a child's individual behaviors and risks, family characteristics, and community-level factors.

Obesity in the US is such a pervasive issue that in 2001 the US Surgeon General called attention to the problem by announcing obesity to be among the most important health concerns facing our country. (16) The health care costs of obesity are staggering, making up 9.1% (\$92.6 billion) of total United States medical expenditures in 1998. (17) The impact of adult obesity has been well described in the medical literature, and it has been increasingly recognized that a child who is overweight is much more likely to become obese in adulthood. Being obese as a 6 year-old imparts a 25% chance of being obese as an adult, and being obese as a 12 year-old leads to a 75% chance of being obese as an adult. (18,19) Overall the likelihood of becoming obese as an adult is twice as high or higher for obese children in comparison to their normal weight counterparts. (19) The likelihood of becoming obese as an adult increases with age and with duration of being overweight as a child. (21)

Adiposity rebound is the period in a child's life, usually around 5 to 6 years old, when they're at the nadir of their body fat. It has been shown that the risk of becoming obese as an adult is associated with an earlier age of adiposity rebound. Also, those children who were heavier at the time of adiposity rebound were more likely to develop problems with overweight as adults. (20) Therefore, timing of adiposity rebound and childhood weight are clearly associated with obesity in adulthood.

Beyond the increasing likelihood of becoming obese as an adult and all the health sequelae that follow, a child who is overweight is at risk for developing a number of medical comorbidities as a child. One common complication is the psychosocial stress of being overweight; approximately 10% of overweight children become clinically depressed. (21) Other complications include sleep apnea and pulmonary insufficiency, aseptic necrosis of the hip, benign steatosis of the liver, and even steatohepatitis with progressive fibrosis of the liver. (22)

One of the most well studied sequella in overweight children has been the dramatic increase in type II diabetes mellitus. The hardest hit populations have been the Pima Indians and other native North Americans, Mexican Americans, Hispanics, African Americans, and non-Hispanic whites. (23) In the period from 1982 to 1994 the incidence of children presenting to a tertiary referral center with type II diabetes mellitus increased ten-fold, and of these patients over 90% were obese ($BMI \geq 37.7 \pm 9.6$). In this 1994 study, type II diabetes accounted for one third of all new cases of diabetes in children aged 10-19 years old, compared to only 3-10% before 1992. Investigators in the study were unable to attribute the increase in type II diabetes to changes in referral or demographic patterns, and they used the absence of islet cell antibodies to confirm the diagnosis of type II diabetes mellitus. (24) Other studies have demonstrated that up to 92% of children diagnosed with type II diabetes mellitus are overweight or obese. (25)

Another major health sequella of childhood obesity is the effect that it has on present and future coronary heart disease. Obesity is by far the most commonly identified cause of hypertension in children and adolescents. (21)

There have been several longitudinal, landmark studies that have examined obesity-related childhood risk factors for coronary heart disease that can be tracked to adulthood, including the Muscatine Study, Bogalusa Heart Study (BHS), and the National Heart, Lung, and Blood Institutes Growth and Health Study (NGHS). (23) The Muscatine Study was begun in 1970 where almost 5000 children had body measurements such as weight, height, BMI, and triceps skin fold thickness as well as documented blood pressure, lipid levels, and smoking status. These children were then followed over a number of years; ultimately over 11,000 children had been screened by 1986. (26) In further tracking of these children, it was discovered that those children in the upper quintile of weight for height in initial measurements had significantly lower high density lipoprotein, higher triglyceride levels, and elevated blood pressures in comparison to their normal weight peers. (27) In another follow up study, original pediatric participants, who now aged between 29 and 37 years, had repeated anthropomorphic measurements taken in conjunction with an electron beam computed tomography to assess for coronary artery calcifications. Those participants who had had higher triceps skin-fold measurements, weight, and BMI as children were significantly more likely to have coronary artery calcifications in young adulthood. (28)

The Bogalusa Heart Study was initiated in the 1970s and also tracked approximately 16,000 children longitudinally with monitoring of coronary heart disease risk factors such as BMI, triceps skin-fold thickness, lipid levels, blood pressure, and smoking habits. The longitudinal results of this study also showed

that an elevated childhood BMI was associated with increased degree of fatty streaks and plaques in childhood and young adulthood. (29) Overall, this longitudinal project showed that obesity influenced a number of cardiac risk factors in children including systolic blood pressure, ratio of total lipoprotein to high density lipoprotein, and plasma insulin levels. (30) The National Heart, Lung, and Blood Institute's Growth and Health Study also discovered that as early as 9 years of age, risk factors for coronary heart disease were present in overweight girls of both ethnicities. (31)

PEDIATRIC TRAUMA

While it is easily recognized that childhood obesity and its resulting sequelae are extremely significant in the American pediatric practice, by far the most common cause of childhood morbidity and mortality is trauma. More children die from trauma (approximately 75% of pediatric deaths) in the United States than from all other etiologies combined. (32) People in the United States have a higher lifetime risk of experiencing a fracture than stroke, type II diabetes mellitus, major depression, or breast or prostate cancer. (33) In 2006 there were close to 10 million nonfatal pediatric injuries in the United States alone. (34) Ankle injuries comprise approximately 4% of these non-fatal injuries. (35) Given the pervasiveness of both trauma and overweight in the pediatric population, it is interesting that the association between the two has only recently begun to be explored.

In adults obesity has been associated with ankle fractures, spontaneous knee dislocations, and hip fractures. (36) Obesity has also been linked with an increased risk for musculoskeletal pain and injuries in the general adult population. (37) One cross-sectional analysis of US adults indicated that over 20% of adults experienced an injury requiring medical attention each year and that the likelihood of sustaining an injury is 15% (overweight) to 48% (class III obesity) greater in a person who is overweight. (38)

Studies of the relationship between overweight and injuries in children have been more limited, whether in exploration of injury rates or subsequent morbidity. A cross-sectional survey of over two-thousand Belgian children was conducted in 1998 to look for an association between weight and injury. Participants were 9-17 years old, and in the year prior to the administration of the survey 37% of the children experienced at least one injury requiring medical attention, and 5% had a severe injury (with at least one night of hospitalization). Of the children presenting with injury more than 15% were classified as obese (BMI percentile ≥ 95). They observed a higher frequency of injury in children who were obese, boys, children who played sports intensely, members of sports clubs, and those who reported more than one episode of physical activity per week. Overall they observed that childhood obesity increased the likelihood of musculoskeletal discomfort, impaired mobility, and injuries, although not the likelihood of more severe injuries. (39)

A chart review of children who had been involved in clinical studies at the National Institutes of Health from 1996 to 2004 was conducted to address any

association between weight and musculoskeletal complaints. Overweight children reported a greater prevalence of fractures, musculoskeletal discomfort, and greater impairment in mobility than the normal weight participants. The most common musculoskeletal complaint in the overweight children was knee pain.

(40)

In another cross-sectional study, Goulding and his colleagues demonstrated that overweight children are at risk for low bone mass and fractures.

(41) Goulding *et al.* also conducted a case-control analysis of 100 girls with forearm fractures matched with 100 girls without forearm fractures. In their study they observed that girls with fractures weighed more than the controls; in fact, a higher fat mass predisposed girls to a two-fold increased risk of fracture. (42)

Addressing a less severe form of injury, sprains, one study followed high school football players for three seasons collecting information on body mass, height, history of previous ankle sprain, and use of supportive bracing, such as ankle taping. They determined that both BMI and previous injury were associated with an increased risk of ankle sprain. Ankle sprain incidence was 0.22 for normal weight players without a history of ankle injury, whereas overweight players with a history of injury had an incidence of 4.27, meaning they were 19 times more likely than their counterparts to experience ankle sprain. (43)

As with adults, overweight children also have increased morbidity following an injury in comparison to their normal-weight counterparts. In a study of children who sustained ankle injury, 50% of those who sustained a fracture and nearly one fourth who simply experienced a sprain had permanent morbidity 3

years later. (44) A prospective cohort study at Cincinnati Children's Hospital looked at the relationship between BMI percentile (BMI-P) and long-term morbidity after an acute ankle sprain. Six months after injury, children who were at risk for overweight or overweight had a relative risk of 1.70 for persistent symptoms. Forty-four percent of overweight children ($\text{BMI-P} \geq 85$ to <95) had persistent symptoms at 6 months, and nearly half of the obese children ($\text{BMI-P} \geq 95$) had symptoms. When they adjusted for BMI-P, they determined that neither sex, ethnicity, nor previous injury was significant in determining long-term ankle morbidity, and that BMI-P was the only significant predictor of long-term ankle morbidity. (36)

Fractures are often the most severe representations of pediatric trauma and the association of obesity and morbidity continues at this extreme. A retrospective review of children between 6 and 14 years of age who experienced operative repair of their femoral fracture was conducted to determine operative morbidity compared to weight for age. This small study determined that overweight children are in fact at risk for an increased rate of postoperative complications from surgical repair of fractures in comparison to their normal weight counterparts. (45)

The current literature has indicated that overweight children are at increased risk for injury and its resulting morbidity than their normal-weight counterparts. As the obesity pandemic and the common pediatric pathology of trauma intersect, a clear understanding of the association between weight and trauma is imperative. Our hypothesis is that overweight children are at an

increased risk for ankle injury. Our research indicates that there has been no previous case-control analysis of minor injuries and being overweight or at risk for overweight in a general pediatric population.

II. METHODS

STUDY DESIGN

The concept for this case-control analysis of overweight and ankle injury was originally detailed by Drs Mark Zonfrillo and David Spiro of the Department of Pediatrics at the Yale University School of Medicine. Further modification and adjustment of the study design and nature were added by the author and members of the Department of Pediatrics.

The case-control analysis was approved by the Yale University School of Medicine's Human Investigation Committee (HIC). The HIC waived the need for written consent by the patient or guardian. Verbal consent was obtained from all patients at the time of enrollment as well as verbal consent from their caretaker if the patient was under 18 years of age. The patients and their families were instructed that they were participating in a study looking at the relationship between weight and ankle injury. Patients were also provided a copy of the HIC approval and brief explanation of the study in either English or Spanish.

STUDY SETTING

The study was executed from June 2005 until July 2006 in the Yale New Haven Hospital Pediatric Emergency Department (PED). This busy, ten-bed, urban PED sees approximately 31,000 visits every year. (46) Cases and controls were between the ages of 5 and 19 years old. Selection of the cases was defined by any acute musculoskeletal trauma to the ankle while the child was ambulatory. Emergency department physicians were asked to enroll cases consecutively, 24 hours a day, in addition to the enrollment of cases by the author. Exclusion criteria for cases included a final diagnosis other than ankle injury or non-accidental injury. Controls were selected based on a chief complaint of headache, fever, or sore throat. Controls were either enrolled by the author or by another research associate (Yale School of Medicine 1st year medical student) as a convenience sample between 8 am and 12 pm. Exclusion criteria for both cases and controls included language other than English or Spanish, inability to obtain height or weight, previous enrollment, and the presence of any underlying medical condition that could significantly affect height or weight (e.g. cancer, severe asthma).

STUDY PROTOCOL

Information collected on every case and control included gender, age, race, insurance status, height, weight, and physical activity score. Weight was

obtained in triage by the nursing staff using a digital scale and height was obtained with a wall mounted stadiometer by the enrolling party (most often the author). All measurements were obtained with the patient in street clothes.

The Physical Activity Score used in the study was designed by Prochaska, Sallis, and Long, and is the result of two sets of questions, the average of which provides a reliable estimate of physical activity behavior and correlates with objective measures of physical activity. It is comprised of a 14 point scale, combining questions regarding recent as well as historical trends of physical activity. (47)

A severity score of the acute ankle injury was also obtained for the cases. This consisted of scoring four components of the injury by an attending physician: swelling, tenderness, function, and fracture. Each aspect of the injury was graded in a three-point manner: 1) Swelling: mild, moderate, or severe; 2) Tenderness: mild, moderate, or severe; Function: 3) minimal loss, difficulty, or unable to bear weight; 4) Fracture: no visible fracture, non-displaced fracture, or displaced fracture.

The author and Dr. Zonfrillo used pediatric growth charts provided by the Centers for Disease Control and Prevention to determine age and gender specific body mass index percentiles (BMI-P), weight percentiles, and height percentiles for all participants. (48,49)

The study was intended to consist of consecutive enrollment of children with ankle injuries, however through the course of the study many eligible patients were not approached when the author was not present. Dr. Zonfrillo then

used the hospital's computerized medical record system (Lynx, Lynx Medical Systems, Bellevue, Wash) to identify those children with ankle injuries who were not approached to participate in the study. Through subsequent chart review we were able to obtain age, gender, insurance status, race, and weight on all non-participant cases. Unfortunately height data is not routinely measured on patients presenting to the pediatric emergency department and was not able to be obtained. Therefore weight percentiles, but not height percentiles or BMI-P, was obtained on all eligible children with ankle injuries who were not approached for inclusion in the study.

STASTICAL ANALYSIS

We used the accepted pediatric categorization of 'overweight' as a BMI percentile ≥ 95 , and 'at risk for overweight' as a BMI percentile ≥ 85 to < 95 as opposed to the comparable adult terms of obese and overweight in our analysis.

Statistical analysis of the data was performed by Drs. Robert Dubrow and Mark Zonfrillo. The comparison of characteristics between cases (participant and non-participant) and controls was accomplished using frequency distributions (chi-square test) and means (*t* test). To calculate multivariate-adjusted odds ratios (ORs) as estimates of relative risk, with the accompanying 95% confidence intervals (CIs), multivariate unconditional logistic regression was employed for cases compared with controls with normal weight children as a reference group. The adjustment variables used in the regression included age,

gender, ethnicity, and insurance status. We also ultimately included month of enrollment as it was determined that the controls were preferentially enrolled in the summer months as compared to the cases and we were concerned for the possibility that BMI-P could be associated with seasonal variations. We converted BMI-P into an ordinal variable with three subsets of normal weight, at risk for overweight, and overweight. This allowed us to test for the significance of the linear trend in the multivariate logistic regression model. We derived the *P* value from the likelihood ratio statistic, with a value of < 0.05 being statistically significant. (46)

The author and Dr. Mark Zonfrillo compared the prevalences of overweight and at risk for overweight to the prevalences that would be expected using national estimates. This was accomplished using age, gender, and ethnicity specific prevalence estimates from the National Health and Nutrition Examination Survey for 2003-2004. (4) A standardized prevalence ration of 1.0 would indicate that the overweight prevalence in controls was equivalent to the national prevalence. (46)

In examination of severity of injury the author used a *t* test, with the assumption of a normal distribution, to determine the significance of the difference between the severity of injury means between the normal weight, at risk for being overweight, and overweight participants enrolled with an acute ankle injury. This was also preformed in the analysis of the activity score of cases and controls.

III. RESULTS

ENROLLMENT

During the period from June 2005 to July 2006 there were a total of 323 patients who presented to the Yale pediatric emergency department with a complaint of acute, accidental ankle injury. Of these children 180 (55.7%) were approached for enrollment in the study by either the author or a physician. A total of 180 controls were also enrolled during this period. In comparing cases and controls, no statistically significant differences between the two groups was noted for ethnicity or month of presentation despite our previous concern (Table 1). The activity score between the two populations also did not vary in a statistically significant manner (Table 1). The two groups did differ in the fact that the participants presenting with acute ankle injury were more likely to be male ($P = 0.09$), have private insurance ($P = 0.06$), and be older ($P < 0.0001$; Table 1). The average age among the cases was 13.7 years, two years older than the controls.

Per calculations by Drs. Dubrow and Zonfrillo, the controls had overweight and at risk for overweight prevalences comparable to the expected national prevalences given the National Health and Nutrition Examination Study from 2003-2004. The standard prevalence ratio was 1.04 for overweight and 1.09 for at risk for overweight (46).

OUTCOMES

As per our hypothesis, cases weighed significantly more than controls as measured both by body mass index percentiles ($P = 0.0001$) and by category distribution into normal weight, at risk for overweight, and overweight ($P < 0.0001$; Table 1). The multivariate analysis performed by Drs. Zonfrillo and Dubrow further demonstrated that there was a significant association between overweight and acute ankle injuries in the study population with a multivariate-adjusted odds ratio of 3.26 (95% CI, 1.86-5.72). (46) Another method of analysis proving the association is by weight category; there is a trend of increasing risk of ankle injury with increasing BMI-P category ($P = <0.0001$; Table 3).

The mean weight percentile for the non-participant cases was lower than the weight percentile of children with ankle injuries who were enrolled to the study. The average weight percentile of the participant cases was 79.4 as compared to 74.0 in the non-participant cases ($P = 0.05$; Table 5). This could suggest a possible bias during physician enrollment towards selection of children who were overweight to participate in the study. As there were no height percentiles available for acute ankle injuries that were not enrolled there is no way to ascertain whether a true bias did exist as BMI-P, the most accurate measurement of overweight, cannot be calculated.

To address this possible bias the author compared the weight percentile means of the controls, the participant cases, the non-participant cases, and all cases combined. When the non-participant cases are compared to controls, no

significant difference in mean weight percentiles exists ($P = 0.1$). When the participant cases are compared to the controls a robust difference exists between the two groups ($P = <0.001$). Therefore the author combined the weight percentile data of the 180 participant cases and 143 non-participant cases to obtain a more representative mean weight percentile for those children with acute ankle injury. When this weight percentile (77.0 ± 24.6) is compared to the controls, a statistically significant difference between the controls and the cases is maintained ($P = 0.02$; Table 5). This indicates that though a possible bias towards enrollment of overweight children in comparison to normal weight children with acute ankle injuries might have existed, there is still a significant difference in weight percentiles between controls and all children who presented to the Yale Pediatric Emergency Department with a complaint of acute ankle injury.

In the original analysis of this issue conducted by Drs Zonfrillo and Dubrow they used a different statistical analysis to prove continued significance of difference between controls and cases. First they combined the participant and non-participant cases into a single case group. They then performed a sensitivity analysis where they used a multivariate-adjusted odds ratio for overweight in comparison to ankle injury through increasingly more unlikely assumptions about the height percentiles of the non-participant cases in an attempt to attenuate the association. In explanation, if one assumes that all non-participant cases were at the 58th percentile for height, to be similar to the controls and participant cases (Table 1), the difference in BMI-P between the controls and combined cases remains significant with an odds ratio of 2.63 (95% CI, 1.63-4.24; P value for

trend < 0.0001). If one calculates increasingly unlikely assumptions for the mean height percentile for the non-participant cases the difference between the BMI-P of the controls and combined cases is still significant at the 95th height percentile. Assuming the non-participant cases have a mean height percentile of 95, the multivariate-adjusted odds ratio is still 1.79 (95% CI, 1.11-2.89; P value for trend = 0.02). (46) In this way, we were able to prove, using the more robust measurement of overweight, BMI-P, that there was a statistically significant difference between controls and all children who presented with ankle injuries despite possible enrollment bias.

The injury severity score amongst those participants presenting with acute ankle injury was made up of a 12 point scale consisting of pain, swelling, loss of function, and fracture per radiograph. The mean injury severity score for the normal weight group (BMI-P < 85) was 7.09, at risk for overweight (BMI-P ≥ 85 to < 95) was 6.83, and for overweight (≥ 95) was 7.20 (Table 2). The combined mean injury severity score for the at risk for overweight and overweight population was 7.06 (± 1.79 ; Table 2). When the at risk for overweight, overweight, and combined cases are compared to the normal weight cases there were no statistically significant differences between the groups ($P = 0.24, 0.38, 0.45$ respectively; Table 4). The lack of association between ankle injury severity and weight is also visually apparent when the two are plotted against each other, with a resultant slope of -0.004 (Graph 1).

IV. DISCUSSION

In our case control analysis we did observe a significant association between overweight and acute, accidental ankle injury as is evidenced by a multivariate-adjusted odds ratio of 3.26 (95% CI, 1.86-5.72; *P* value for trend < 0.0001). (46) However, no association between overweight and increasing severity of injury was discovered (Table 4, Graph 1).

BIAS

Through examination of those children who presented to the Yale pediatric emergency department with a diagnosis of acute ankle injury who were not enrolled in the study, it becomes clear that an enrollment bias could have existed. As the persons responsible for enrollment were physicians in the emergency department, and not part of the research staff, it is likely that since they were aware of the study's hypothesis they preferentially enrolled overweight children with ankle injuries. As we could not determine the heights of non-participant cases we cannot be certain that a selection bias did in fact occur. However, although this complication might diminish the magnitude of the association between overweight and ankle injuries, analyses indicate that the statistical significance is still robust.

In the author's analysis of weight percentiles, the combined participant and non-participant cases weighed significantly more than the controls, with a

difference of mean weight percentile of 6.7% ($P = 0.02$). In another approach, Drs. Zonfrillo and Dubrow proved, even with the unlikely assumption that non-participant cases had an average height percentile of 95 for their age and gender, that the multivariate-adjusted odds ratio would have been 1.79, with a 95% CI of 1.11-2.89 and P value for trend of 0.02. (46) This indicates that by analyses of weight percentiles and body mass index percentiles, a significant association exists between ankle injury and overweight. Given the above discussion, we conservatively estimate that the risk of injury in overweight children to be twofold greater than the risk of injury in their normal weight counterparts.

It is possible that the lack of correlation between injury severity and increasing weight was a result of bias. There could have been some bias introduced by the fact that the injury severity score was subjective and the cases were graded by over 17 different physicians. However, given the fact that the graders knew the hypothesis of our study, it seems more likely that if bias did exist, it would have favored the existence of a difference in severity based on weight. Another concern, however, is that we employed a grading system that has not been externally validated. Swelling, tenderness, function, and fracture seem to be the most logical categories for grading ankle injury, and as our results are in keeping with other reports regarding injury severity and weight (39), it is likely that interobserver bias did not exist. It is also possible that the occurrence of fractures was so small in our sample that we were unable to detect a statistically significant increased likelihood of fracture in children who are overweight, and that in a larger sample this association would appear (a Type II error).

In examination of our data it does not appear that the above results could be explained by any other forms of bias. It is unlikely that bias in the selection of the control group occurred as the controls had similar prevalences for overweight and at risk for overweight as is expected by national estimates. The cases and controls did differ in the fact that the cases were enrolled throughout the day whereas the controls were enrolled from 8am to midnight. However, most ankle injuries occur and are brought to the emergency department during these same hours. An unlikely bias that could exist is that children who present with ankle injuries to the emergency department weigh more than the children with ankle injuries who do not visit the emergency department, however we are unaware of any evidence to support this hypothesis. (46)

COMMENTARY

Given the results from our case control analysis and previous studies exploring the relationship between overweight and injuries in children, the mechanism for this association is intriguing. Many people have postulated that altered biomechanics in overweight children is the reason for increased rates of injury, however there are actually few studies directly linking musculoskeletal injury in the obese to altered biomechanical processes. (50, 51)

In regards to our study population of acute ankle injuries there could be a few mechanisms responsible for the increased risk of ankle injuries in overweight children. In an overweight child, the ankle bears more weight than in comparison

to a normal weight child, which could increase the risk of acute ankle injuries. Also, poor balance could increase the risk for ankle injuries in overweight children as postural sway (52) has been identified as a risk factor for ankle injuries. Additionally, overweight male adolescents display poorer single-limb stance balance than their normal weight counterparts. (53)

In a more general approach to the causal relationship between overweight and injuries in children, commonly accepted knowledge dictates that the increased weight load on the functional and structural components of the locomotor system in obese persons leads to aberrant mechanics on the connective tissue mechanics of the patient's body. The exact mechanism of this aberrant mechanics is unknown, but emerging evidence indicates effects on both bone and soft-tissue structures such as tendons, fascia, and cartilage. (50) Furthermore, both metaphyseal-diaphyseal and anatomic tibiofemoral angle measurements were significantly more malaligned in overweight children than in normal weight children, indicating a possible mechanism for the association of overweight and knee injuries in children. (40)

In adults, higher body weight has been shown to be protective against osteoporosis and is the best predictor of bone mineral density. (54,55) In contrast, a high body weight in children is associated with low bone mass and increased rate of fractures. However we did not observe this association in our study, possibly secondary to type II error. In children, use of bone mineral content is preferred to analysis of bone mineral density as bone mineral density is associated with bone and body size, which creates difficulty in interpretation of the bones of

growing children. (54) In an Australian cohort study, Goulding and his colleagues examined whether body adiposity was associated with a lowered bone mineral content. They obtained heights and weights of 336 children between the ages of 3 to 19 years and then used dual energy X-ray absorptiometry to determine body composition, bone mineral content, and bone area of their study participants. The children were then assigned to groups based on their body mass index percentiles: normal weight (BMI-P < 85), overweight (BMI-P \geq 85 to < 95), and obese (BMI-P \geq 95). Their results revealed that actual measured bone mineral content and bone area were less for the overweight and obese children than the predicted values. However, the absolute bone mineral content in these populations was higher than in the normal weight reference group. The authors describe this situation of lack of increased bone mineral content in comparison to weight a mismatch between body weight and bone development. Their belief is that an increase in weight precedes an increase in bone mineral content, thereby making the bones in obese children more fragile based on their body weight requirements. (56)

Another study of increased fracture risk in overweight children puts forth a different theory of the mechanism of the association. Skaggs and his colleagues suggest that the increased fracture rate in overweight children is as a result of smaller cross-sectional area of the bone. Their study consisted of 50 girls, aged 4-15 years, who presented with a forearm fracture. They matched their participants for age, weight, height, and tanner stage with controls. Even though they removed weight from their original study design, they noted that the girls with

fracture were within the 90th percentile for age-adjusted weight. Ultimately Skagg and his colleagues determined that the overweight child with a small radial cross-sectional area was at the most risk for fracture because of the greatest weight stress to bone area. (57)

Another mechanism that has been put forth to explain the association between overweight and fracture or injury is the idea that overweight children have altered life style factors that could lead to decreased bone mineral density. Weiler and his colleges have suggested that the decreased bone mineral content of overweight children merely reflects lifestyle habits that lead to diminished bone mass. (58) Most implicated in the accumulation of bone mineral content in children has been their physical activity; decreased physical activity is associated with lowered bone mineral density. (50) Some studies have shown that overweight children with fractures have the same activity level as their peers; however other studies have shown indirect evidence that obese children are less physically active. (59) If decreased physical activity plays a role in the development of injuries in overweight children it is not clear whether this is through affects on bone mineral content or through fitness components such as impaired balance or reduced strength and coordination. Also, it is difficult to determine whether the obese child is at risk for fractures and injuries because of inherent vulnerabilities (bone mineral content, impaired balance, etc), or from mechanisms of the fall itself. (50) There has been some evidence that overweight children are less skilled at falls than their normal weight counterparts in a study examining traumatic injuries to the teeth in overweight children. (60)

Given the multifactorial nature of injuries in children, it is most likely that overweight acts as a permissive factor in musculoskeletal disease by interacting with and increasing the effects of other risk factors (50) such as bone mineral content and biomechanical concerns such as skeletal alignment and muscle strength. Studies linking exact biomechanical mechanisms in the obese are scarce, and further research into this area, as well as physical activity in overweight children, are necessary steps in the analysis of this pertinent issue.

In regards to our study population with acute ankle injuries, future research should perhaps address the association of overweight with other known risks for ankle injuries such as limited dorsiflexion and impaired proprioception. (46) Further examination also needs to be conducted in regards to the association between overweight and other forms of injury, overweight and physical activity level, and overweight and injury severity. Pediatric ankle injuries are complex and difficult to classify objectively (61), therefore there needs to be the creation of a validated injury severity score to address this issue.

V. CONCLUSIONS

This study is the first case control analysis in a pediatric emergency department to demonstrate that overweight children have a two-fold increased risk of developing injuries in comparison to their normal weight counterparts. Our results, however, did not indicate an association between overweight and injury severity, likely because of type II error. Future studies regarding the association

between overweight and injury should explore the relationship with physical activity, injury severity, and the biomechanics behind these associations. The results from our study may have implications on the management of pediatric trauma in the emergency department, as well as demonstrating the need for increased intervention targeting obesity in the pediatric population.

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VIII. FIGURES

Table 1: Baseline Characteristics of Cases and Controls (46)

Characteristic	Cases (n = 180)	Controls (n = 180)	P value
Male sex, No. (%)	105 (58.3)	89 (49.4)	0.09
Age, mean (SD), yr	13.7 (3.0)	11.6 (4.1)	<0.0001
Ethnicity, No. (%)			0.82
White	58 (32.2)	63 (35.0)	
Black	67 (37.2)	70 (38.9)	
Hispanic	51 (28.3)	44 (24.4)	
Other	4 (2.2)	3 (1.7)	
Insurance*, No. (%)			0.06
Private	84 (46.7)	62 (34.6)	
Medicaid	80 (44.4)	94 (52.5)	
Other	16 (8.9)	23 (12.8)	
Month of Presentation, No. (%)			0.29
January-March	35 (19.4)	48 (26.7)	
April-June	37 (20.6)	28 (15.6)	
July-September	65 (36.1)	67 (37.2)	
October-December	43 (23.9)	37 (20.6)	
Activity Score, mean (SD)	9.1 (4.5)	9.2 (4.5)	0.42
BMI percentile			< 0.001
< 85	75 (41.7)	109 (60.6)	
≥ 85 to < 95†	40 (22.2)	35 (19.4)	
≥ 95‡	65 (36.1)	36 (20.0)	
BMI percentile, mean (SD)	80.1 (23.2)	69.7 (26.6)	0.0001
Weight percentile			0.001
< 85	73 (40.6)	105 (58.3)	
≥ 85 to < 95	46 (25.6)	41 (22.8)	
≥ 95	61 (33.9)	34 (18.9)	
Weight percentile, mean (SD)	79.4 (23.9)	70.3 (26.3)	<0.001
Height percentile			0.78
< 85	128 (71.1)	133 (73.9)	
≥ 85 to < 95	29 (16.1)	28 (15.6)	
≥ 95	23 (12.8)	19 (10.6)	
Height percentile, mean (SD)	57.2 (30.7)	57.8 (29.8)	0.84

* n = 179 for controls because of a missing value

† at risk for overweight

‡ overweight

Table 2: Ankle Severity in Cases

BMI Percentile	N	Mean severity score (SD)
< 85	75	7.09 (2.09)
≥ 85 to < 95†	40	6.83 (1.39)
≥ 95‡	65	7.20 (1.99)
≥ 85*	105	7.06 (1.79)

† at risk for overweight
‡ overweight
* at risk for overweight and overweight combined

Table 3: Multivariate-Adjusted Odds Ratios for Ankle Injuries in Relation to Overweight and at Risk for Overweight (46)

BMI percentile	Cases (n = 180)	Controls (n = 180)	Multivariate-Adjusted Odds Ratio (95% CI)
< 85 (normal weight)	75	109	1.00
≥ 85 to < 95 (at risk for overweight)	40	35	1.73 (0.95-3.14)
≥ 95 (overweight)	65	36	3.26 (1.86-5.72)
<i>P</i> value for trend			< 0.0001

Table 4: Injury Severity in of at Risk for Overweight and Overweight in Comparison to Normal; means analysis (*t* test)

BMI percentile as compared to normal weight cases (BMI < 85)	<i>t</i> score	<i>P</i> value
≥ 85 to < 95 (at risk for overweight)	0.71	0.24
≥ 95 (overweight)	0.32	0.38
≥ 85 (at risk and overweight combined)	0.10	0.45

Graph 1: Injury Severity Score in Cases vs Body Mass Index Percentile

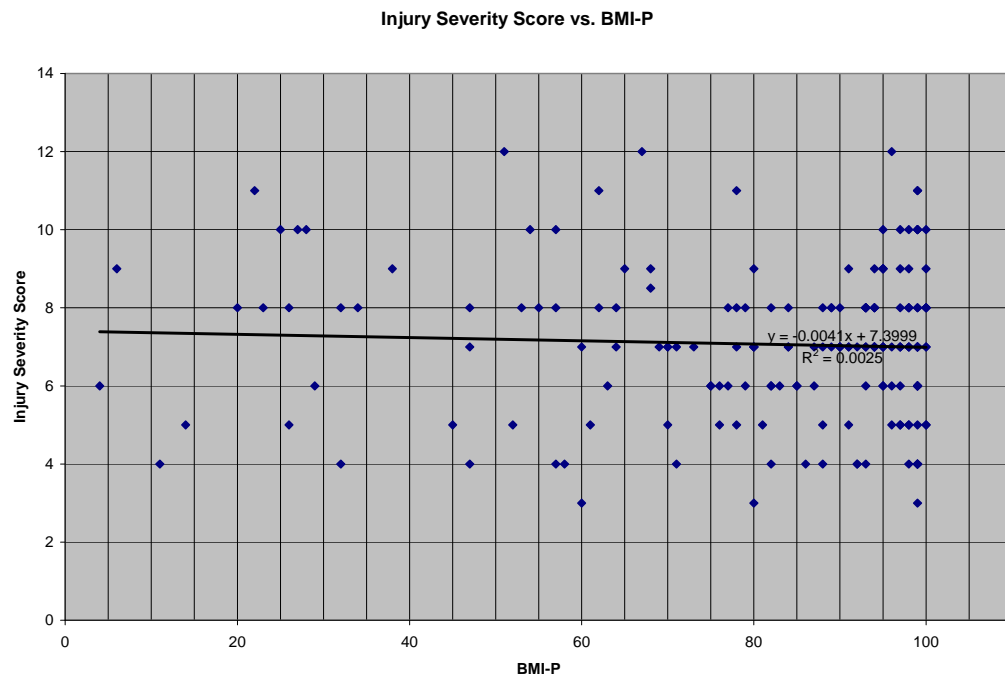


Table 5: Weight Percentiles for Participant and Non-participant Cases in Comparison to Controls

	N	Weight Percentile, mean (SD)	<i>P</i> value
Controls	180	70.3 (26.3)	
Participant cases	180	79.4 (23.9)	< 0.001
Non-participant cases	143	74.0 (25.2)	0.100
Participant and Non- participant cases combined	323	77.0 (24.6)	0.002

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